Faculty of Engineering

PERFORMANCE OF FREE SPACE OPTIC TRANSMISSION UNDER HAZE IMPACT

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Bachelor of Engineering (Hons) in Electronic (Telecommunications)

2017

UNIVERSITI MALAYSIA SARAWAK

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PERFORMANCE OF FREE SPACE OPTIC TRANSMISSION UNDER JEREBU (HAZE) IMPACT

AIVEA NUR PUTRI BINTI HASSAN

A dissertation submitted in partial fulfillment

of the requirement for the degree of

Bachelor of Engineering with Honours

(Electronic Telecommunications)

Faculty of Engineering

Universiti Malaysia Sarawak

2017

To my beloved family and friends

ACKNOWLEDGEMENT

First and foremost, all praises and thanksgiving to Allah the Almighty, for gracing me with strength to complete my thesis. Alhamdulillah. I would like to express my deepest gratitude to my supervisor Dr. Abdul Rahman Bin Kram for his unlimited guidance and support through this thesis. This thesis could not have been completed without his supervision and inspiration. I would like to express my appreciation to all staff of Malaysian Meteorological Department in Kuching branch for their assistance in data collection. My gratitude also goes to the cluster members of staff school of Electronic Engineering Telecommunication, for their assistance and contribution of my thesis and to all my friends for their moral support throughout my study in UNIMAS. Last but not least I would like to express my sincere thanks to my family for being patient and supported me throughout my study. Without their patient and support, I would not have made it till to the end.

ABSTRACT

Free Space Optic (FSO) or ‘fibreless fiber optic’ is a technology that transports data wirelessly from one place to another via lasers technology due to their coherence nature. Infrared light is used to provide full-duplex capability for transmission of data as compared to traditional fiber optics and RF transmission to curb last mile bottleneck problem due to implicit advantages such as affordable, easy to install and high bandwidth for a license-free spectrum. This technology is a Line Of Sight (LOS) technology where the connection is established between transmitter and receiver at the air at long distance for 4km. However, this technology is vulnerable to adverse atmosphere conditions. This thesis is aim to investigate the attenuation effect over the point-to-point FSO communication linkage. The thesis carried out under the tropical rainforest climate and the sample is taken at Sarawak region. That provide by Malaysia Meteorological Department (MMD). Haze is a type of weather condition that can contribute to high atmospheric attenuation and capable to degrade the FSO link performance. This weather is usually contributed by smoke, road dust, and other particles emitted directly into the atmosphere. These particles often grow in size as humidity and density of haze increases, further impairing visibility. Two approaches have been used in this research. The first is an extensive studies in modeling haze attenuation to investigate the Sarawak weather pattern in order to determine how the attenuation be able to occur in FSO communication linkage. This atmospheric model for haze is constructed from scattering coefficient, atmospheric attenuation and geometric loss equation. Optisystem software versions were used as a second approach to simulate and observe the effects attenuation over the link system. The performance of this FSO system is investigate under different parameters wavelength, size of aperture for transmitter and receiver, beam divergence angle and receiver sensitivity.

ABSTRAK

Ruang Bebas Optik atau ‘gentian optik fibreless’ ialah teknologi yang menghantar data secara tanpa wayar dari satu tempat ke tempat lain melalui teknologi laser kerana sifat kepaduan mereka. Cahaya infra merah digunakan untuk penghantaran data dari segi laser mendapat lebih tarikan and penglibatan penyelidik berbanding gentian optik dan penghantaran RF untuk membendung “Last-mile Bottleneck Problem” atau masalah penghantaran data di sekeliling kerana terdapat banyak kelebihan seperti harga yang berpatutan, mudah dipasang dan bandwidth yang tinggi serta mengguna spektrum yang tidak memerlukan lesen. Teknologi ini adalah Lajur Pandangan di mana sambungan diwujudkan antara pemancar dan penerima di udara pada jarak sejauh 4km. Walau bagaimanapun, teknologi ini adalah terdedah kepada keadaan atmosfera buruk. Tesis ini bertujuan untuk menyiasat kesan atenuasi ke atas perhubungan komunikasi Ruang Bebas Optik dari titik ke titik. Kajian dijalankan di bawah iklim hutan hujan tropika dan contoh data diambil di kawasan Sarawak yang disediakan oleh Jabatan Meteorologi Malaysia (JMM). Jerebu ialah satu jenis keadaan cuaca yang boleh menyumbang kepada pengecilan atmosfera yang tinggi dan mampu menjejaskan prestasi penghubung Ruang Bebas Optik. Cuaca ini biasanya disebabkan oleh asap, debu jalan, dan lain-lain zarah yang dipancarkan terus ke dalam atmosfera. Zarah-zarah ini sering terdapat dalam saiz seperti kelembapan dan kepadatan jerebu yang tinggi, selanjutnya menjejaskan penglihatan. Dua pendekatan telah digunakan dalam kajian ini. Yang pertama adalah kajian yang menyeluruh dalam model atenuasi jerebu untuk menyiasat corak cuaca di Sarawak untuk menentukan sejauh mana atenuasi boleh berlaku dalam komunikasi perhubungan Ruang Bebas Optik. Model gangguan-gangguan atmosfera ini adalah di bina daripada persamaan serakan kofisien, atenuasi gangguan udara dan kehilangan geometric. Software Optisys versi telah digunakan sebagai pendekatan kedua untuk simulasi dan mengamati kesan atenuasi ke atas sistem hubungan. Prestasi sistem Ruang Bebas Optik ini diselidiki di bawah perbezaan parameter-parameter jalur lebar, saiz lubang cahaya penghantaran dan penerima, sudut sinar capahan dan kepekaan penerima.

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LIST OF ABBREVIATIONS

BER	-	Bit Error Rate
CO_2	-	Carbon Dioxide
DSL	-	Digital Subscriber Line
FIR	-	Far Infrared
FSO	-	Free Space Optic
IR	-	Infra Red
LAN	-	Local Area Network
LASER	-	Light Amplified Spontaneous Emission
LOS	-	Line of Sight
O_2	-	Oxygen
O_3	-	Trioxygen
T1	-	or T1
RF	-	Radio Frequency

CHAPTER 1

INTRODUCTION

1.1 Introduction

Early experiments in Free Space Optics (FSO) was demonstrated by Alexander Graham Bell, which introduced his invention of the telephone in the late nineteenth century [1]. He used beams of light as a medium to transmit voice conversations through the free air space as the name stated no medium is used, which he dubbed the ‘photophone’ by sunlight. Although, Bell’s experiment never translated into a commercial reality, the principle of FSO was proved. He was conducted telephone wireless transmission between two buildings for a distance of some 700 feet apart, further the first in the world success. Then, FSO has long been used by the military and space agencies such as NASA to provide high-speed wireless communications using non-radio media [1]. Scientist have successfully developed Light Amplification by Stimulated Emission of Radiation (LASER) technology. Finally, optical communication was shortly discovered after the development of LASER technology. In the mid-1960’s, NASA initiated experiments to utilize the laser as mean of communication between the Goddard space Flight center and Gemini-7 [1].

FSO communication is an optical communication in which optical data transmitted wirelessly from one place to another by using light propagating in free space. Fiber optic cables containing the light pulses in the fiber glass due to impractical, FSO technology is useful for physical connection and it transmitted in a narrow beam through the atmosphere. Light travels through air faster than it does through glass, so FSO is classified as optical communications at the speed of light [1]. The bad weather occurring throughout the year in tropical temperate region such as rain, fog, dust and haze is able to distort the quality of FSO transmission. Maximum range of terrestrial links is limited (less than 10km) [1]. Nowadays, the FSO communication system are being increasingly considered as an attractive option for the rapid provisioning of multi-gigabit per second links [1].

FSO is a laser-driven, fibreless technology that supports high bandwidth with no interference issue, not require any license or leased-line rental costs. This technology is easy to install connections for golden mile or last mile telecommunications and can function over distances of several kilometers as long as there is a clear line of sight between the source and the destination, and the optical receiver can reliably decode the transmitted information [2]. FSO link provide the transmission capacity to overcome information bottlenecks. This high data rates application can send voice, video conference and real-time image transmission, and also to achieve affordable communication for everyone, at anytime and place [1]. The communication capabilities is enable not only human to human communication and contact, but also human to machine and machine to machine interaction. The communication will allow our visual, audio, and touch sense, to be contacted as a virtual 3-D presence [3].

1.2 Background

Nowadays, telecommunication technologies were widely used with sophisticated equipment and produced a variety of new invention due to high demand from enterprise customers and service providers. There are a few options data communication technology that exists in global market.

First of all is fiber-optic cable refers to provide optical communication which is the most reliable and obvious choice. This technology need to dig and also can be pulled through underground ducts to install. This way of digging can delay on time and associated costs to lay fiber often make it uneconomically. It becomes a “sunk” cost and cannot be re-deployed due to deployment of fiber if a customer relocates or switches to competing service provider further extremely difficult to recover the investment in reasonable timeframe [4].

RF (Radio frequency) technology is the second alternative. RF is a mature technology which has been applied in a lot of industries in recent years that offers longer ranges distances than FSO, but RF-based networks require spectrum licensing. The current RF bandwidth ceiling is 622 megabits and the optical capacities cannot scale to 2.5 gigabits. RF does not make any sense of economic for service providers looking to extend optical networks compared to FSO [4].

Another option is wire- and copper-based technologies such as cable modem, T1s or DSL. Nowadays, the percentage of buildings connected to copper is available almost everywhere compared to fiber but it is still not an alternative way to solve the connectivity bottleneck. Bandwidth scalability is the biggest hurdle. The bandwidth limitations of 2 megabits to 3 megabits makes them marginal solution, even a good day even the copper technologies only may ease some short-term pain [4].

The fourth-and often most viable-alternative is FSO. This technology is suprisingly simple. It approach has a number of advantages and an optimal solution such as given its optical base, bandwidth scalability, speed of deployment (hours versus weeks or months), re-deployment and portability, and cost-effectiveness (on average, one-fifth the cost of installing fiber-optic cable) [4].

1.3 Problem Statement and Motivation

FSO has the potential to provide high of data rate, license-free transmission and secured but it highly poor in bad weather conditions such as haze, rain, fog and heat. In this thesis, it focused on haze phenomenon that sufficient smoke, dust and other dry particles obscure the clarity of the sky. This phenomenon can potentially to attenuate the beam light due to the vulnerable of FSO. Bad weather conditions also be able to hinder the light passage through the combination of scattering, absorption and turbulence. This haze phenomenon is essential to interrupt and disturbance the performance and availability of FSO transmission.

FSO systems is possible to mount inside buildings, simplifying wiring and cabling and reducing the need to compete for roof space. This system is operated in favorable environment due to permit its equipment. But, a preliminary stage is vital before we install the FSO by investigate analysis of local weather patterns condition and recognize the prediction of worst scenario performance. This stage is important to secure the operating of FSO with sufficient transmission power and minimal losses, even during bad weather conditions.

In this research focused on haze effects upon the FSO system performance. The cause of increases atmospheric attenuation are such as the selection of divergence angle, receiver area, transmitter area and distance between transmitter and receiver will be examined to minimize attenuation effect on FSO. OptiSystem software is a simulation that carried out in this research to investigate BER, received power and eye patterns upon link performance. Detail explanation research will be elaborated in this project.

1.4 Objectives

FSO system research projects have been conducted to learn more about its potential in the future. The system is a telecommunications technology that is increasingly being used around the world. Studies using FSO system has been created for the use of this system is limited. The study was made on the understanding signal propagation effects of the weather. The study should be carried out at specific locations based on weather statistics to estimate the availability of the link. The main objective of this research has focused on the following two objectives:

i. To study the atmospheric model to perform the weather data using scattering coefficient, atmospheric attenuation and total attenuation due to haze condition.

ii. To develop and to study the performance of FSO using software OptiSystem software under difference beam divergence, size of apertures, wavelength channel and receiver sensitivity.

1.5 Scope of Works

Design scope model is important which can conduct the implementation of this project successfully. Figure 1.1 is an illustration scope of this project. Generally, FSO system can be classified into indoor system and outdoor system. This research is concentrate to outdoor FSO communication system due to the indoor FSO communication system are not affected by the atmospheric effects and confined only to short distances. The weather condition that investigated in this research focus on haze which under the tropical rainforest climate. The two objectives of this research is achieve by dividing into two parts which are technical studies and simulation. Technical studies is focus on atmospheric attenuation that including the scattering coefficient, geometric loss and total attenuation that contribute to increasing of attenuation due to scattering effect factor in FSO communication. Another part is simulation with using the OptiSystem software that will observe the performance of FSO system under the different parameters wavelength, beam divergence angle, receiver sensitivity, aperture size for transmitter and receiver due to the effect of attenuation.

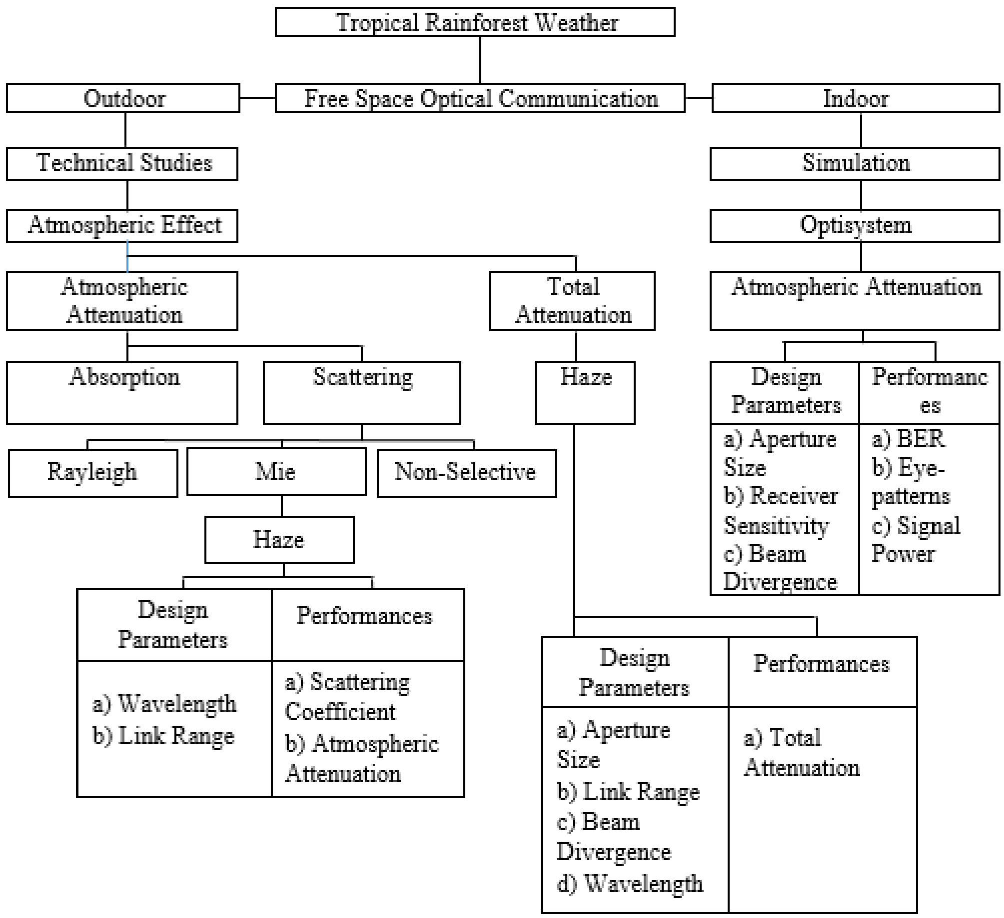

Figure 1.1: Model Showing the Scope of Study

1.6 Organization Thesis

Chapter 1:

First chapter of this report is about project introduction. FSO systems suffers from adverse atmospheric phenomenon such as haze but it has been of interest in years due to high-speed, improved capacity, cost effective and easy to deploy wireless network in urban area. Therefore, this objectives of project is aim to analyze and stimulate an accurate FSO model on propagation of optical signal due to the weather effects.

Chapter 2:

Chapter 2 covers the literature review of FSO system. The study showed the development of FSO communication, the technology used, comparison broadband access technology and also it advantages and disadvantages. Understanding on this chapter helps in the simulation in the next chapter.

Chapter 3:

This chapter is explained detail about research methodology. The chapter shows how the simulation of software tools are being utilized. Simulation specification is included in doing this simulation.

Chapter 4:

The results of the simulation are presented in the fourth chapter that contribute the comparison and analysis are made regarding to the result obtained.

Chapter 5:

This chapter is made to conclude the entire all about this project and some recommendations are suggested for further study.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Free Space Optic

Free Space Optics (FSO) has been used for more than a decade as a short/medium distance point-to-point, point-to-multipoint connectivity solution in enterprise LAN markets. FSO system is used light to transmit data like fiber optic communication but free space optic as the name stated no medium is used instead of the transmitted in a narrow beam through the atmosphere. It is a full-duplex (bi-directional) capability that provide from Line Of Sight (LOS) broadband communication technology which each side consist a transmitter and receiver. Laser is coherent and high power further it is widely used in this system. The two optical transceivers are then accurately aligned to each other with a clear line-of-sight. Generally, the FSO system works over distances of several 0.1 to 5 km and the optical transceivers are mounted on building rooftops or behind windows [5].

2.2 FSO Communication System

FSO communications systems are known as a wireless point-to-point communications systems. This systems delivered data by infrared line-of sight (LOS) directed beams of light, such as lasers beam that focused on highly sensitive photon detector receivers or modulated visible as optical communication signal. The useful of this technology is about physical connection that not require cables or fibers connected between transmitters and receivers even in difficult locations such in cities [6].

The collection of the photon stream and transmission of digital data containing a mix of video images, radio signals, Internet messages, or computer files are able in receivers that are telescopic lenses in FSO technology. The capacities that available in the range of 100 Mbps to 2.5 Gbps, and data rates of demonstration systems as high as 160 Gbps. The modulation of optical signal via transmitter is to carry data report then the optical receiver collects all of the energy of the optical signal and convert it into an electrical signal. The operation on electrical signal in optical receiver recover the modulated data and, in some applications, align the receiver to optimally receive the optical signal [6].

Optical transmitters and receivers are configured in FSO communication system to transmit and receive optical signals propagating in free space, also waveguides are not needed to connect the transmitter and receiver. The limitations of free space optical communications systems associated with the installation and maintenance do not exhibit such guided wave optical communication system that rely on optical fibers between transmitter and receiver. Moreover, the data rates (with very low errors) of FSO systems are comparable to optical fiber transmission systems [7].

RF, or radio frequency provide a bandwidth of optical transmission but it is not wider than FSO. As general, optical signals are more focused than RF signals further more difficult to intercept and less likely to cause interference with other transmissions [7].

FSO has a device, called a “telescope” to transmit infrared eye-safe (limited laser